Research Proposal: Study of Hadronic Parity Violation

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At high energies the weak interaction of leptons–electrons, muons, taus and their neutrinos–can be described accurately. The same cannot be said about the weak interactions between hadrons, which are difficult to study since they are obscured by the much larger effects of the strong and electromagnetic forces. Experiments can measure weak interactions by isolating their parity-violating effects. This is often achieved by looking for an asymmetry in some physical process, a difference in cross-section between two possible initial spin states. This proposal is for work on such an experiment at Los Alamos, the $n + p \rightarrow d + \gamma$ experiment, which plans to use the pulsed neutron source at LANSCE to produce a polarized cold neutron beam incident on a proton target. The experiment will measure the asymmetry A_γ of the correlation between the neutron polarization direction and the direction of emission of the photon in the reaction $n + p \rightarrow d + \gamma$.

In the standard model, the weak force is mediated by the exchange of $W^\pm$ and Z^0 bosons. The weak interaction between hadrons takes place through $W^\pm$ and Z^0 boson exchange between the quarks which make up the hadrons. However, the range of the nucleon-nucleon interaction is much longer than the range of the weak bosons. Long-range strong forces between nucleons are mediated by the exchange of mesons, so one model for low-energy weak interactions between nucleons is a one-meson-exchange potential. One nucleon-meson vertex includes the weak interaction with W or Z exchange, and the other vertex is simply a strong interaction. Theoretical calculations of these types of weak interactions are difficult because it is unknown how the strong interactions modify the weak interactions. The goal of the $n + p \rightarrow d + \gamma$ experiment is to measure one of the weak coupling constants for the nucleon-nucleon interaction, H_π^1, which is directly related to A_γ, and to compare it to theoretical predictions. Also, values of H_π^1 from previous experiments with ^{18}F and ^{133}Cs disagree, and theoretical estimates do not clearly favor one result. The LANSCE $n + p \rightarrow d + \gamma$ experiment result for H_π^1 should resolve this discrepancy and determine if the one-meson-exchange model is correct. The standard model predicts a large contribution from the weak neutral current to H_π^1, but the existing measurements indicate that H_π^1 is small and the weak neutral current contribution is largely suppressed.

The $n + p \rightarrow d + \gamma$ experiment will be difficult, attempting to measure A_γ with uncertainty 0.5×10^{-8}, which means detecting 4×10^{16} gammas from the process. According to theoretical estimates, this will yield a 10% measurement of H_π^1. My contribution to the experiment will be to work with the collaboration to complete building of the experiment. I will be responsible for building a crucial component of the experiment, namely, the CsI gamma detector system. With a few months of running time, the $n + p \rightarrow d + \gamma$ experiment should resolve the discrepancy between the ^{18}F and ^{133}Cs experiments, a publishable result. To reach the proposed uncertainty of 0.5×10^{-8} will take one year of running time.

Experiments using low-energy polarized neutron beams at LANSCE will allow me to continue my personal research interests in the physics of what one might call ‘ordinary’ matter: protons, neutrons, and electrons. Electrons and their behaviors under the electromagnetic and weak forces are well understood, but the nucleons, being composite particles, have more complicated interactions. My previous research at SLAC used a high-energy polarized electron beam to measure the spin structure functions of the nucleons. Polarization provides a powerful tool for the study of nuclear and particle physics–as it does in the $n + p \rightarrow d + \gamma$ experiment, which using a polarized cold neutron beam, will resolve important theoretical and experimental discrepancies and test our understanding of the standard model.